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TITLE: ANALYZING-POWER FORMALISM FOR THREE-BODY FINAL STATES

AUTHOR(S): G. G. Ohlsen, R. E. Brown, F. D. Correll, and R. A. Hardekopf

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LOS ALAMOS SCIENTIFIC LABORATORY
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ANALYZING-POWER FORMALISM FOR THREE-BODY FINAL STATES*

G. G. Ohlsen, Ronald E. Brown, F. D. Correll, and R. A. Hardekopf
Los Alamos Scientific Laboratory, Los Alamos, New Mexico 87545, USA

In connection with measurements[1] being carried out on the three-nucleon reaction $^1H(\vec{d},pp)n$, we have derived various relationships important for extraction of analyzing powers from data on reactions involving three particles in the final state. We present here, for spin-1/2 and spin-1 polarized beams, several of the pertinent results, detailed derivations of which will appear elsewhere.[2]

We choose a Cartesian coordinate system at the reaction site to describe the vector and tensor analyzing powers and take the z axis to be in the beam direction. With respect to the symmetry axis Z of the ion source, the beam polarization is described by its vector polarization p_Z and its tensor polarization p_{ZZ}. At the reaction site, this "quantization axis" makes a polar angle β with respect to the beam direction (z axis) and an azimuthal angle ϕ with respect to the y axis. For a two-body final state it is conventional to take the y axis perpendicular to the reaction plane. For a three-body final state the two geometries of Fig. 1 would appear reasonable, where ϕ_1 and ϕ_2 are the azimuthal angles of the two particles detected in a kinematically complete experiment, and the momenta are viewed in projection on the xy plane. In certain circumstances the symmetric choice illustrated in Fig. 1(b) introduces significant simplifications, and because of this we propose that <u>Fig. 1(b) be adopted as a y-axis convention for work involving three-body final states</u>.

It will be recalled that, for two-body final states as described in the conventional coordinate system, parity conservation requires that the analyzing powers A_x, A_z, A_{xy}, and A_{yz} vanish. The same is true for a kinematically <u>incomplete</u> experiment in which only one of the three particles in the final state is detected. In general, for a kinematically <u>complete</u> situation, parity conservation does not require any of the analyzing powers to vanish;[3] however in special circumstances some important restrictions do arise.

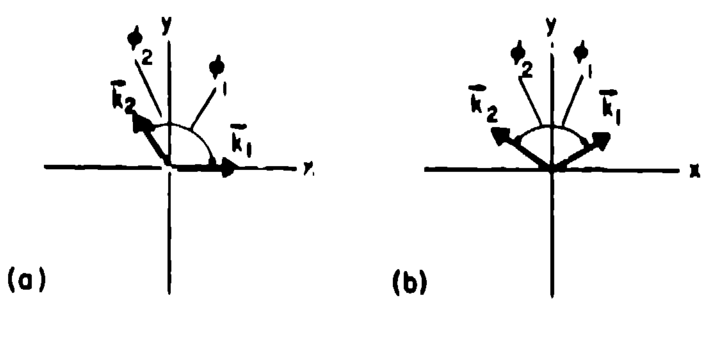

Fig. 1. Two possible y-axis definitions.
In (a), $\phi_1=90°$; in (b) $\phi_1=\phi_2$.

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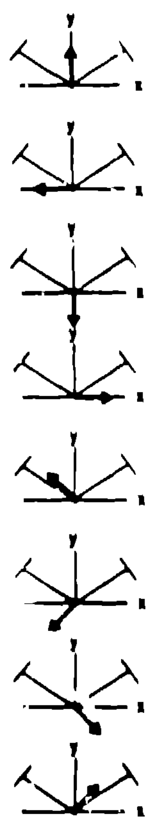
The yield I for a reaction induced by a spin-1 beam can be written in the form

$$I = I_0[1 + (3/2)p_Z C_z + (1/2)p_{ZZ}C_{zz}] \ . \tag{1}$$

In the analogous expression for a spin-1/2 beam, the coefficient of p_Z is unity and the term involving p_{ZZ} is absent. In either case I_0 is the unpolarized yield and C_z, C_{zz} are linear combinations of the vector and tensor analyzing powers, respectively. The particular linear combinations which occur depend upon the orientation of the spin quantization axis with respect to the chosen coordinate system. In Figs. 2 and 3 we list the relationships between C_z, C_{zz} and the analyzing powers for some common geometries. There the beam direction is out of the figure, the xy projection of the spin quantization axis is indicated by the heavy arrow, and the detector positions are also shown. Even though the symmetric choice for the y axis is depicted, the relations given in Figs. 2 and 3 are valid for any other orientation of the detectors.

$\beta = 90°$



ϕ	C_z (COEFFICIENT OF $\frac{3}{2}p_Z$)	C_{zz} (COEFFICIENT OF $\frac{1}{2}p_{ZZ}$)
0°	A_y	A_{yy}
90°	$-A_x$	A_{xx}
180°	$-A_y$	A_{yy}
270°	A_x	A_{xx}
45°	$-\frac{1}{\sqrt{2}}A_x+\frac{1}{\sqrt{2}}A_y$	$-A_{xy}-\frac{1}{2}A_{zz}$
135°	$-\frac{1}{\sqrt{2}}A_x-\frac{1}{\sqrt{2}}A_y$	$A_{xy}-\frac{1}{2}A_{zz}$
225°	$\frac{1}{\sqrt{2}}A_x-\frac{1}{\sqrt{2}}A_y$	$-A_{xy}-\frac{1}{2}A_{zz}$
315°	$\frac{1}{\sqrt{2}}A_x+\frac{1}{\sqrt{2}}A_y$	$A_{xy}-\frac{1}{2}A_{zz}$

Fig. 2. Coefficients of Eq.(1) for β=90°.

We finally discuss two special situations. First, in coplanar geometry ($\phi_1 = \phi_2 = 90°$ in Fig. 1) parity conservation causes the same analyzing powers to vanish that vanish for two-body final states. Second, if <u>identical</u> particles are detected at <u>equal</u> polar angles, <u>and</u> if the symmetric choice of y axis is made [Fig. 1(b)], then parity conservation imposes an odd-even relationship on the analyzing powers at symmetric points on the kinematic locus (the curve in a two-dimensional plot of detected particle energies E_1 vs E_2 which indicates the energies permitted by conservation of energy and momentum). Thus, if we define an arc length s measured along such a

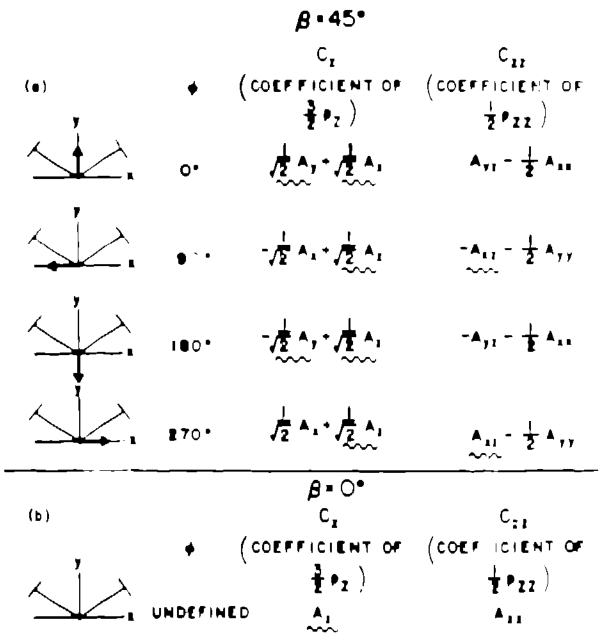


Fig. 3. Coefficients of Eq. (1) for β = 45° and 0°.

locus with an origin (s=0) at a symmetric-energy point ($E_1 = E_2$), then +s and -s refer to symmetric points on the locus at which the values for E_1 and E_2 are interchanged.[1] The underlined analyzing powers in Figs. 2 and 3 are those quantities whose magnitudes are equal but whose signs are opposite at symmetric points (±s), and the other analyzing powers have equal magnitudes and signs at symmetric points. This also implies the interesting result that the underlined analyzing powers vanish at symmetric-energy points ($E_1 = E_2$).

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1. Contributions to this symposium. See also R. E. Brown, G. G. Ohlsen, F. D. Correll, R. A. Hardekopf, and N. Jarmie, Bull. Am. Phys. Soc. 23, 953 (1978); F. D. Correll, G. G. Ohlsen, R. E. Brown, N. Jarmie, R. A. Hardekopf, and P. Schwandt, Bull. Am. Phys. Soc. 24, 569 (1979); F. D. Correll, R. E. Brown, R. A. Hardekopf, N. Jarmie, G. G. Ohlsen, J. M. Lambert, P. A. Treado, I. Slaus, and P. Schwandt, Bull. Am. Phys. Soc. 25, 556 (1980).

2. G. G. Ohlsen, R. E. Brown, F. D. Correll, and R. A. Hardekopf, Nucl. Instrum. Methods, to be published.

3. L. D. Knutson, Nucl. Phys. A198, 439 (1972).